The evolution of the morphological scale of early-type galaxies since z=2 from HST-NICMOS observations

P. Saracco, M. Longhetti, S. Andreon, A. Mignano

Abstract

We present the morphological study of a sample of ~**30 early-type galaxies** (ETGs) **spectroscopically confirmed at *1.2<z<2 (<z>~1.5)***. The analysis is based on **HST-NICMOS** observations in the **F160W filter.** We derive the **effective radius Re [kpc]** and the **mean surface brightness (SB) μ_e [mag/arcsec2]** in the rest-frame R-band. We find that the SB of these early-types should get fainter by ~2.5 mag from z~1.5 to z~0 to match the SB of the local early-types with comparable R_e. This evolution exceeds by a factor two the luminosity evolution expected for early-types in this redshift range and more than a factor three the one derived from the observed luminosity function of galaxies. Thus, luminosity evolution alone does not account for the higher compactness of early-types at z~1.5. A possibility is to assume that galaxies evolve also in their morphological scale, i.e. the effective radius Re of a galaxy increases from the epoch of its formation towards z=0.

1. Sample and HST-NICMOS observations

The sample is composed of **28 early-type galaxies (ETG) with spectroscopic confirmation (24 of them) at 1.2<z<2 and deep HST-NICMOS observations picked out** from the samples of Longhetti et al. (2007), GDDS (Abraham et al. 2004), Moriondo et al. (2000) and HDFS-NICMOS.

NICMOS observations in the **F160W (λ~1.6 μm)** filter sampling the **rest-frame R-band** at the redshift of the galaxies are available for the whole sample: with the **NIC2** (**0.075 "/pix**) camera for 50% of the sample and with the **NIC3 (0.2 "/pix)** camera for the remaining 50%.

2. Morphological parameters

We derived the effective radius r_e *(arcsec)* and the mean surface brightness (SB) **$<\mu>_e$** within r_e of galaxies by fitting a **Sersic** profile to the observed profiles

$$I(r) = I_e e^{-b_n[(r/r_e)^{1/n}-1]}$$

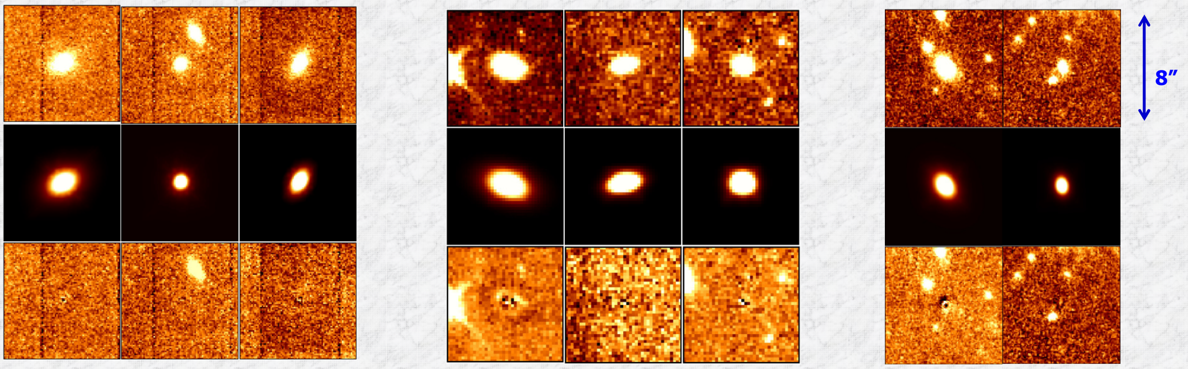
n=4 and **n=1** values define the **de Vaucouleurs** and to the **exponential (disk)** profiles respectively. We used **galfit** (Peng et al. 2002) to perform the fitting after the convolution with the NIC2 and NIC3 PSFs. The **NICMOS images of 8 galaxies of our sample** are shown in the upper row of the figure below as example. The best-fitting Sersic model and the residuals of the fitting are also shown in the middle and in the lower panels respectively.

NIC2 images (0.075 "/pixel) Longhetti et al. (2007) sample.	NIC3 images (0.2 "/pixel) GDDS sample.	NIC3 images (0.2 "/pixel) HDFS-NICMOS
z=1.34 z=1.40 z=1.45	z=1.65 z=1.73 z=1.85	z=1.55 z_{phot}=1.94

NICMOS-images

2-d Sersic model

Residuals



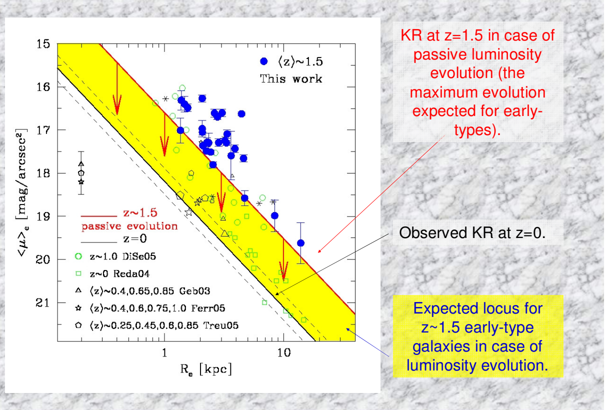
3. The Kormendy relation

The **Kormendy relation** (**KR**, Kormendy 1977) is a linear scaling relation between the logarithm of the effective radius ***R_e***[Kpc] and the mean SB ***$<\mu>_e$*** [mag/arcsec^2]

$$<\mu>_e = \alpha + \beta \log(R_e)$$

The early-types follow this tight relation with **a fixed slope *β~3* up to *z~1* while the zero point *α* is found to vary with *z* reflecting the luminosity evolution of galaxies.**
Fig. 1 shows our galaxies (**blue filled circles**) at ***1.2<z<2*** in the ***[<μ>$_e$,R_e]*** plane together with those from lower redshift samples (open symbols).
All the data have been corrected for the cosmological dimming factor $(1+z)^4$. Thus, any deviation from the KR at z=0 reflects the evolution of the SB due to the luminosity and/or size evolution of galaxies.

Fig.1 - Mean surface brightness *<μ>$_e$* vs effective radius *Re*



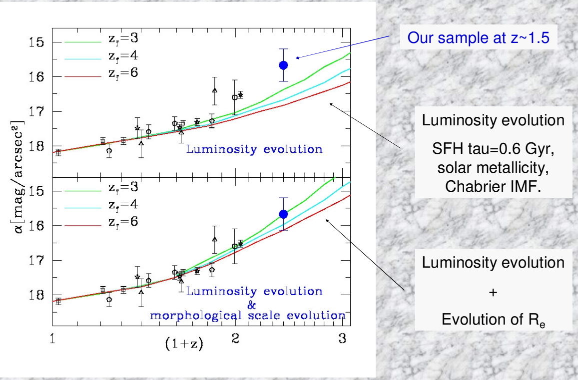
4. The evolution of the morphological scale

In **Fig. 1** the black solid line is the **observed KR in the *R* band at *z~0***:
$<\mu>_e$=18.2+2.92 log(R_e);
the red solid line is the **expected KR in the *R* band at *z~1.5:***
$<\mu>_e$=16.6+2.92 log(R_e)
in case of passive luminosity evolution, an upper limit to the luminosity evolution of ETGs.
These two relations encompass the (yellow) region in the *[μ_e,R_e]* plane where *z~1.5* ETGs are expected. In fact, all the ETGs of our sample drop out this region. Their SB exceed by *Δ<μ>$_e$~1* mag the one expected in the case of pure luminosity evolution for constant *R_e*, **i.e. luminosity evolution alone does not account for the observed compactness of ETGs at high-z.**

In **Fig. 2** the values of the **zero point *α*** of the KR in the rest-frame R band derived from various samples at *z<1* are shown (black symbols) together with the one from our sample (blue filled circle). **The curves show the expected evolution of *α* for different formation redshift z_f** in case of **Luminosity Evolution (LE, upper panel)** and **of evolution of *R_e* in addition to the LE (lower panel)**

$$R_e(z) = R_{e,z=0} \times (0.5+z)^{-1};\ z > 0.5$$

Fig.2 – The evolution of the zero point of the Kormendy relation



Conclusions

The ETGs at *z~1.5* are characterized by a SB higher then their local counterparts with comparable *Re.* The luminosity evolution does not account for the observed excess. An evolution of the effective radius from the epoch of their formation towards *z=0* is required. **Two hypothesis can be done to account for such evolution:**
- **color gradients whose intensity increases at younger ages (i.e. going to high-z) due to a differential star formation history from the outer to the inner regions of ETGs. These gradients would be affected also by different k-corrections;**
- **a structural evolution, i.e. the system relaxes from high to low redshift, implying higher central velocity dispersion in high-z early-types then in the local ones.**

Both these hypothesis are tightly linked to the formation of ETGs. Thus, the understanding of this evolution would open a new window in the comprehension of the formation of ETGs.